Astronomy 1001 - Notes

KeyWords Chapter 1

Cosmological Principle
Earth to Quasars, the Grand Tour
The Size of Space.
Matter in the Big Picture (hydrogen to people)
Science and the scientific method.

Cosmological Principle – The Cosmological Principle states that there is nothing unique about the Earth, whether in its position in the universe, or in the natural laws that govern it. Natural laws are consistent across the universe. What happens on a lab bench here on the Earth, would also happen on a table on a planet in another galaxy.

The **speed of light** in a vacuum is a constant speed of 300,000 km/s. The speed of light is the maximum speed that anything can travel. The distance that light travels in one year is referred to as a light year, and it is a measure of *distance* not time. One light-year is equal to 9,460,730,472,580.8 km., or about 10 Trillion kilometres.

Earth to Quasars:

Moons and smaller debris orbit planets.
Planets, in turn, along with asteroids and comets, orbit stars. The Earth is a planet.
Stars are the dominant central bodies of 'stellar systems'. Our star is called the Sun. It dominates our system, which we call the solar system.
Our Sun, along with several hundred billion other stars, orbit the centre of our galaxy, which we call the Milky Way. The Milky Way is an enormous spiral shaped grouping of stars which is over 100,000 light years in diameter. It is, just one of the billions of galaxies we observe in known space.
The Universe is everything that exists. It is tens of billions of light years in diameter, and contains hundreds of billions of galaxies.

Scale Models

∑ Proportionally, the atmosphere is to the Earth as the film of paint is to a baseball.
∑ Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune, [Pluto]
∑ If the sun is a grapefruit, then the Earth is a dot on the wall approximately ten meters away. Jupiter is a large marble on the corner of Inglis and Robie; Saturn is a small marble on the roof of the Dalplex; Uranus is a BB at the Willowtree; Pluto is a grain of sand half way across the new bridge to Dartmouth.
At this scale, the entire solar system fits comfortably into metro. The edge of the Oort Cloud extends to Fredericton in all directions. The nearest star is a grapefruit in Thunder Bay, Ontario. There is another star in Greenland, and another in England, etc. At this scale, the Milky Way galaxy would extend to the edge of our solar system.
∑ The Universe has as many galaxies as there are grains of sand on a beach, and each of those galaxies has as many stars as there are grains of sand on a beach.

Each of the following is 'very roughly' 100,000 times bigger than the one below it: They thus represent equal size steps in scale.
Universe
Galaxy
Solar System

Earth
Halifax
Human
Cell
Atom
Quark.

Matter in the big Picture:

Interstellar material, produced in the original “big Bang”, when the universe formed 13.7 billion years ago. Consisted entirely of a mixture of hydrogen (75%) and Helium (25%). This mixture still makes up the vast majority of the matter in the universe. Now, there is in addition to those two gasses, a 1% mix made up of 99% ‘second tier elements’, which are produced in stars and expelled back out into interstellar space. Oxygen, carbon, silicon, aluminum, iron, neon, sulphur, and nickel . The last 1% of 1%, consists of everything else.

99% - H, He + 1% metals
1% metals consist of 99% the main "metals" --> made inside stars
(Oxygen, carbon, silicon, aluminum, iron, neon, sulphur, and nickel),

And 1% of the 1% -> everything else (gold boron silver uranium and so on...)

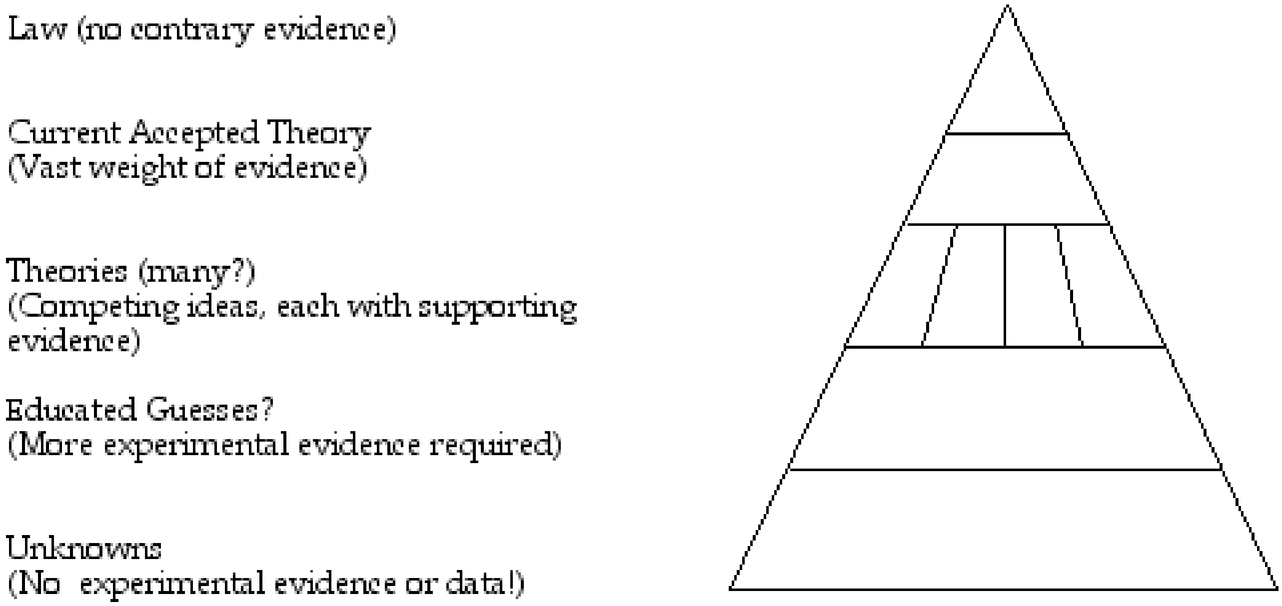
Although only 1%, the metal content is very important as it produces planets, upon which we depend as places to live!

Composition of the Universe
- 75 % Hydrogen
- 24 % Helium
- 1 % Metals [Metals are anything other than Hydrogen and Helium]
  Metal Breakdown:
  99% O,C,Ne,Fe,N,Si,Al,S.
  1% remaining, all others.

The **Scientific Method** is the way scientists make decisions. Sort of a structured learning process by which we determine the truth. It began to take shape with the ancient Greeks, but wasn’t really developed until the renaissance period in western Europe. It allows one to formulate a hypothesis about a situation, and then objectively test that hypothesis through rigorous experimentation to determine whether the hypothesis was true or false.

The **Scientific Pyramid** is a hierarchy of scientific knowledge.

1. Scientific Laws – At the top of the Scientific Pyramid are scientific laws. These have only evidence supporting them, and no evidence refuting them. (e.g. Gravity)
2. Accepted Theories – Accepted theories are those which have a large amount of data supporting them, but there is also a small amount of data contradicting them. They are generally accepted to be true, but research goes into trying to make them scientific laws. (e.g. HIV causes AIDS)
3. Competing Theories – Competing theories are two opposing theories, each with a mass of data supporting them. (e.g. Light as a particle, light as a wave – there is evidence supporting both).
4. Educated Guesses - One has a hypothesis, but not the evidence to support it.
5. Unknown



If the experiment supported the original hypothesis, it will tend to move upwards in this hierarchy, if it refuted the hypothesis, it would tend to move downward. All ideas and scientific theories will sit on this structure. However, in real world science, the results of an experiment are not, in themselves enough to make a change. The experiment must be available to be examined by others (**published**) and to be repeated **(repeatability)** by others. These processes together are called **"peer review"** and are vital to ensure the accuracy of the results.

There are other concepts worth mentioning. Science is by its very nature very skeptical. No changes are introduced unless evidence is strong. when in doubt, the scientist will go with the accepted answers. Furthermore, the amount and quality of evidence required is related to the size of the change. To quote Carl Sagen, "Extraordinary claims require extraordinary evidence."

Another principle that science employs is called "Ockcam's Razor", which states, " When multiple solutions to a problem present themselves, the simplest is the most likely solution".

This "method of determining truth" is not only applicable to fields of scientific endeavor. When you explore a problem with your computer, the process you go through is essentially a looping repeat of many small scientific explorations. The scientific method is so engrained in our modern thinking that we use it all the time without knowing it.

There is a wealth of information about the Scientific Method on the web, you are encouraged to explore the concept further.

Keywords Chapter 2

Ancient Astronomy Worship and Why?
Historical Astronomy Time Keeping
Daily rotation Effects;
- **24 hours**
- **paths in sky**
- **Fig 2.8**
- **Corolis Effect**

Annual Revolution
- **Time Keeping/ Seasonal Skies**

Aberration
Seasons n causes
Moon:
Motions
Phases
Eclipses
Lunar
Solar Partial/Annular/Total

Ancient Astronomy Worship and Why?

In prehistorical times, people no doubt saw the heavens as a magical place, as it had powerful influence over their lives, as well as remaining 'untouchable'. (You can walk towards the Moon for your whole life and yet never get any closer to it, unlike most other things in their world.) The sky was clearly of importance to them, as many ancient cave drawings often show an astronomically theme.

Historical Astronomy Time Keeping

Although there are still religious overtones, most historical observatories, such as the stone circles of the plains native americans or the Chomsongdae tower appear to have been primarily time keeping sites. As the ancient societies started to develop and get more complex, the need to know the time (remember , there were no clocks back then) grew in importance.

Daily Effects.

Because of the fact that we are standing on a spinning sphere, there are some profound effects upon the celestial sphere above our heads. Everything in the sky rises in the east, crosses the sky and sets in the west. The whole starry sky appears to rotate about a point high up in the North (at our latitude) called the North celestial Pole.

The height of the North Celestial pole above the horizon is the same as the observer's latitude on the Earth.

Rotation – the motion of one body spinning on its axis. *The axis is inside the body. ie., The earth rotates 360° in 24 hours. (Actually, 23 hrs and 56 minutes, the extra four minutes allows the planet to catch up with the Sun!)*

Corolis Effect – Read Ch 2 for more details. Basically, it affects large bodies like hurricanes, ocean basins, cruise missiles, etc., *not* toilet bowls and sinks.

Annual Revolution:

Because the Earth revolves around the sun once per year. **There are some changes in the sky which occur on that time frame** We define night time as being on the Earth , facing away from the Sun. Thus we look out in different directions at different times of the year. This means that the stars we see change over the course of the year. Thus the stars in the sky can be thought of as **seasonal.**

Revolution - the path one body takes when it goes around another. *The axis of rotation is outside the body. ie, The earth revolves around the sun.* The specific path the Earth takes in its yearly revolution is called the *ecliptic.*

Stellar Aberration – Light coming from stars above is slightly bent due to the Earth's motion. This is hard evidence which proves the Earth goes around the sun.

Seasons and causes:

Because the Earth rotation is about a 'tilted axis', we here in the northern hemisphere are sometimes tilted towards the Sun, and sometimes tilted away from the Sun. The tilt of the Earth and its position in its orbit determine the angle of the sun in the sky. During northern summer, when the Earth's north pole is tilted towards the Sun, we experience two profound effects which effect out weather. (**causes of the seasons**).

1) There is longer periods of sunlight each day, thus the Earth's surface warms up more than it cools down.

2) The sun we do receive is higher in the sky, strikes the ground at a steeper angle and is thus more concentrated.

Moon Motions.

The moon revolves around the Earth in 28 days, a period of time that has come down to us as the 'month'. The orbit it follows is elliptical, as well as tilted about 5 degrees to the ecliptic. The moon rotates is sync with its revolution, and thus keeps the same face towards us at all times. There is no dark side of the moon , but there is a far side of the moon that is largely hidden from us.

Moon phases – A phase is caused by different angles of illumination. The first quarter moon is a 'half circle on the right side' because the sun is illuminating the spherical moon form that side. This bears thinking about. Any sphere lit from one side will show a semi circle of light. This can be readily demonstrated with a flashlight, and a ball in a dark space.

We call the two weeks during which the moon is 'growing" the waxing phases, and the two weeks during which the moon is shrinking the 'waning ' phases.

Waxing phases appear to the left of the sun in the sky when the Moon is growing, *waning* phases appear to the right of the sun in the sky, when the moon is shrinking.

Crescent - 45º
Half Moon - 90º
Gibbous - 135º
Full Moon - 180º

- A new moon appears very close to the sun in the sky, and thus is hidden.
- A full moon is opposite the sun in the sky, thus it rises at sunset and sets at sunrise, being high overhead at midnight.
- There is a relationship between the Moon's phase, and when it will rise. This is best visualized by means of a diagram. But there are few statements one can make.

The time of day gives the sun's position. Phase of moon gives angular distance from the sun. Waxing vs. waning gives left or right respectively.

Eclipses.

An **eclipse** is when one astronomical object casts a shadow upon another.

A lunar eclipse occurs when the moon passes through the shadow of the Earth. One might think this would happen every full moon, but the moon's orbit is tilted by 5º to the ecliptic. Thus the moon oscillates from 5º above to 5º below the Earth's shadow, which is why an eclipse does not happen every time their is a full moon.

When a lunar eclipse does happen, the moon does not completely disappear, but instead turns reddish as a result of sunlight be refracted through the Earth's upper atmosphere, being

bent down into the shadow. if you were on the moon, looking at the Earth, you would see the sun sliding behind the Earth, and the earth edge would start to glow like a ring of sunset.

Why does the moon turn red and not black during a lunar eclipse? Because Earth's atmosphere scatters short wave light more then longer wavelengths. As the sunlight passes through the Earth's upper atmosphere, it is bent (refracted) in towards the Moon. But because of this scattering, only long wave light (red) remains. The darker the eclipse, the dirtier the atmosphere.

Line of Nodes – one of two points where the moon's orbit crosses the Earth's ecliptic. If a new moon or a full moon occurs on the line of nodes (when the moon is at the correct angle to fall within the earth's shadow) an eclipse occurs.

A solar eclipse occurs when the sun is either partially or totally obstructed by the moon. (It is an interesting coincidence that the Moon is the same size in our sky as the sun. Both objects are 100 times as far away as they are in diameter.)

Stated from Wikipedia another way, the Sun's distance from the Earth is about 400 times the Moon's distance, and the Sun's diameter is about 400 times the Moon's diameter. Because these ratios are approximately the same, the Sun and the Moon as seen from Earth appear to be approximately the same size: about 0.5 degree of arc in angular measure, about the size of an aspirin held at arm's length.

Solar eclipses come in three flavours:

1) total
2) annular
3) partial

Umbra - the darkest part of the shadow, in which light from the sun is completely blocked. During a total solar eclipse the viewer is located inside the umbral shadow of the moon.

Penumbra – The outer part of the shadow where the light source is only partially blocked. viewing the eclipse from the penumbral shadow results in a **partial solar eclipse**. People who are not 'on the line' but off to one side will get to see a partial eclipse.

If the diameter of the moon in the sky is less than the diameter of the sun in the sky,, because the Moon is near apogee, (the farthest point from the Earth in its orbit) an **annular eclipse** occurs. (The umbral cone does not reach the Earth's surface.) people in this case who are one the line will see the moon centered on the sun, but a ring of sun will still be visible around the edge. The sun turns into a brilliant "o" in the sky.

If you are 'on the line', and the Moon is close enough, you will see the very striking **total solar eclipse**, an event not to be missed. The sky darkens but stays bluish, the air cools, birds roost, streetlights come on. the sun 's outer atmosphere becomes visible, an eerie circle of white streamers radiating outwards away from the sun's surface. Pictures do not do it justice.

Keywords Chapter 3

Copernicus
- **The Idea /calendar troubles**

Tycho
- **Observations**

Kepler

Data reduction
3 laws

Galileo
Lecturer (Introduced common sense)
Telescope
Clash with Roman Church

Newton
Conclusions (WHY!)
Laws of Motion
Law of gravity

ORbital Diagram Types and velocities)

Centre of Gravity

Kepler's Generalized third law.

The Five Important People of Astronomy.

1. Nicholas Copernicus -> IDEA

- Due to inaccurate calculations, the calendar of the time was off by two weeks, and it had the winter solstice occurring on December 9th instead of December 23rd; this needed to be corrected, so the church approached Copernicus to investigate.
- Copernicus revisited the Greek idea of a sun-in-center solar system, and he recognized the simplicity of this line of thought. Copernicus applied a sun-in-center model, and many of the errors were eliminated, but the calendar was still significantly off because he used circular orbits in his model.

2. Tycho Brahe -> DATA

- Tycho Brahe was one of the greatest observational astronomers of all time. His father saved the King's son from drowning, and as a reward his father requested a top-of-the-line observatory for Tycho. Tycho also had extremely sharp vision and he was an astronomy nut. His sharp vision, his love for astronomy, and his observatory allowed him to accumulate a huge block of astronomical data for 25 years which was extremely accurate.

3. Johannes Kepler -> CALCULATOR

- Kepler was a famous mathematician who basically invented numerology; he was hired by Tycho as an assistant. After Tycho's death, Kepler worked on his data and figured out that the orbits of the planets were elliptical. When he applied elliptical orbits to Copernicus' sun-in-center model, all of the errors went away.

<u>Kepler's Laws</u>

1. Planets have elliptical orbits with the sun at one foci and empty space at the other.
2. Planets sweep out equal areas in equal times, therefore planets must move faster when they are closer to the sun.
3. The square of the period of a planet's orbit in years, is equal to the cube of the semi-major axis of a planet's orbit in AU.

4. Galileo Galilei OBSERVER.

- An incredibly smart (and perhaps a little crazy!) individual who figured out how motion works. He was the first person to use a telescope to make significant discoveries about the heavens and to report those discoveries to the common man.
- He published in languages that the laymen could read, as well as published to public media. He refuted Aristotle thought of an Earth-centric universe, and contributed much to the discussion of how things moved.

Kepler's Three Laws

1. Planets move in elliptical orbits with the sun at one foci and empty space at the other.
2. Planets sweep out equal areas in equal times, and therefore planets must be moving fastest when they are closest to the sun.
3. The square of the period of a planet's orbit in years is equal to the cube of a planet's semi-major axis in AU.

5. Isaac Newton The great CONCLUSION

Son of an English pastor, poor childhood but grew into an amazing scientist. Major contributions to the fields of dynamics, gravity, motion, optics, mathematics. Arguably the father of Physics. Newton first formulated the law of gravity, as well as the laws of motion.   He essentially answered the question "WHY?" for many of the observed properties of the universe of his time.

Velocity – the speed and direction of an object's motion.
Acceleration – any change in velocity.
Mass – the property of an object that determines its resistance to changes in motion, or, the measure of an object's inertia.

The **Law of Gravity** states that all objects fall to the ground at the same speed, and therefore gravity must pull harder on heavier objects.

$$FGrav = G \frac{(m_1 - m_2)}{r^2\_}$$

where: g - gravitational constant
m_1 – mass of first object
m_2 – mass of second object
r_ - distance between masses .

By examining this formula, we know that the larger the surface radius of a planet, the less the surface gravity, and vice versa. For instance, if there are two planets, planet A and planet B, both of whom have at the same mass, but planet A has twice the radius of planet B, then planet A will have 1/4 th. the surface gravity.

Newton's Three Laws
1. Objects at rest stay at rest, and objects in motion stay in motion.
2. Motion is changed only when acted upon by imbalanced forces. F=ma
3. Forces come in pairs which are equal in intensity but opposite in direction.

Orbiting means "falling around the world".

Orbital Velocity Diagram Description

1. If Object Velocity < Orbital Velocity, then the object will have a Ballistic Trajectory, and it will fall back to the ground.
2. If Object Velocity = Orbital Velocity, then the object will go into a Circular Orbit.
3. If Object Velocity > Orbital Velocity and if Object Velocity < Escape Velocity, then the object will go into an elliptical orbit.
4. If Object Velocity = Escape Velocity, then the object will go into a Parabolic Orbit.
5. If Object Velocity > Escape Velocity, then the object will have a Hyperbolic Orbit.

The velocities required for a Circular Orbit (2) and a Parabolic Orbit (4) are far too precise, and these two occurrences are mathematically improbable. Therefore, one of three things will happen when something is shot into space: it will either fall back onto the ground, or it will go into an elliptical orbit, or it will go off into space, never to return.

All Bound Orbits are therefore ellipses; Parabolic Orbits and Hyperbolic Orbits are called unbound orbits, because they are not bound to the object that they are orbiting.

KeyWords Chapter 4

Worlds Structure
Pieces -
- **Molecules**
- **Atoms**
- **Subatomic particles**
- **Quarks**

Forces
- **Gravity**
- **Electromagnetic**
- **Weak Nuclear**
- **Strong Nuclear**

Radioactivity
- **Types and dangers**
- **Sources**
- **Half lives and dangers**
- **Radio dating**

Light is a particle
Light is a wave
Photons, absorption/emission

Em Spectrum
- **History**
- **Photon Energy**
- **Danger**
- **Temperature**
- **Wavelength / Frequency**

Heat Transfer
- **3 Ways Conduction/convection/radiation**
- **Temperature, what is it? absolute zero.**
- **Thermal equilibrium**
- **Black Body Radiation**

Atmospheric absorption
- **Satellites and why**
- **Greenhouse effect**

Spectral lines
- **Emission and Absorption**
- **Kirchoff's laws**
- **Doppler shift**
  - **Examples of things learned.**

Relativity intro and when.
Extra solar planets and how.

Element – an element is one of 92 naturally occurring substances (e.g. oxygen) or one of 20

man-made ones. Each element is chemically defined by the number of protons in its nucleus.

Compound – a substance consisting of two or more elements bonded together by chemical means. (e.g. H20)

Molecule – the smallest piece of an element or compound that still retains all of the properties of that element or compound. Molecules consist of atoms chemically bonded together. (e.g. the smallest piece of H20 that is still technically water)

Atom – an atom is the smallest piece of an element that still retains all of the properties of that element. It consists of a nucleus (proton +, neutron /) and an electron cloud.

Proton (+ charge), Electron (- charge), and Neutron (no charge)

- The number of protons in a nucleus decides the **specific type of element the substance will be**. It largely determines the materials physical properties, and also perhaps to a lesser extent, its chemical properties.
- The number of electrons normally is equal to the number of protons, and **renders the atom electrically neutral**. Electrons have a large role in the element's chemical properties.
- The number of neutrons in the nucleus decides atomic **stability**.
- An **isotope** is an atom with a different atomic weight., therefore has a different number of neutrons then the 'normal'.

Electrical forces are what make objects feel solid. If it was not for the EM force, your hand could pass through the table with ease. This is becaue atoms are 99.9999 percent empty space!

The Four Forces of Nature

1. Gravity – Very, very long range. Compared to the other forces, gravity is weak. It only seems strong when you are dealing with massive objects. (like planets!) It is always positive. It acts between all matter.
2. Electromagnetic Force (EM) – Acts over long ranges, and is a strong force. It requires charges to be present, and it can be either positive or negative. EM Force accounts for 99% of our lives.
3. Strong Nuclear Force – Acts only over atomic distances, but is awesomely powerful. It is the binding force in atomic nuclei, and it is always positive.
4. Weak Nuclear Force – The "Bookkeeping Force". The WF decides the correct number of neutrons to go into a nucleus, and therefore it determines nucleic stability. Positive or negative; within the nucleus; very powerful.

Radioactivity – can be thought of as the release of atomic particles or radiation from the nucleus of an atom. This usually occurs when the nucleus is unstable because the Weak Nuclear Force is not being obeyed. (essentially the wrong number of neutrons) The type of radiation depends on what gets thrown off of the nucleus (gamma, beta, etc.)

Half-life - The amount of time that it takes for one half of a material to undergo nuclear breakdown. Carbon goes from C14 to C12 in 6000 years.

Light as a Particle, Light as a Wave - It is actually both!

Light has both the properties of being a wave, and the properties of being a particle (this is known as 'The Duality of Light'). For instance, light is made up of particles called photons, but it is also referred to in wavelengths.

The color white results from all of the light bouncing off of an object and returning to our eyes. The color black results from all of the light being absorbed into an object and nothing gets returned to our eyes. Other colors result from all other portions of the visible light spectrum

being absorbed but that color, which gets bounced back to our eyes. (e.g. a red sweater is red because all of the white light from the sun gets absorbed by the sweater except for the red wavelengths, which get bounced back and are detected by our eyes.)

Atoms can absorb and emit photons. The photon will be absorbed if the atom can 'use' its energy, usually for changing the orbit of an electron. The electron vanishes into the electron, which moves to a higher energy orbit. (further from the nucleus). This process is called **absorption**. At some later time, the electron will drop back down to a lower energy orbit, and release the photon back into space. This process is called **emission**.

Ground State – The lowest possible energy state that an electron can occupy.

Electromagnetic Spectrum

Gamma Ray | X-Ray | UV Radiation | Visible Light | IR Radiation | Micro Waves | Radio Waves
|
Violet, Indigo, Blue, Green, Yellow, Orange, Red

Microwaves are designed to make water particles wiggle, and thus heat up. Since humans are essentially bags of water, microwaves can burn us.

Ionizing Radiation - Anything to the left of violet on the electromagnetic spectrum; dangerous.

ELECTROMAGNETIC SPECTRUM

Higher <------ Photon Energy ------> Lower
Greater <------ Damage Potential ------> Lower
Higher <------ Temperature ------> Lower
Higher <------ Wave Frequency ------> Lower
Shorter <------ Wave Length ------> Lower

Temperature – the quantity of subatomic movement.
- Absolute Zero = -273 ºC or -459 ºF. Absolutely no particle motion.
- In space there is no liquid; all matter goes from solid to gas.

The three methods of heat transfer are:

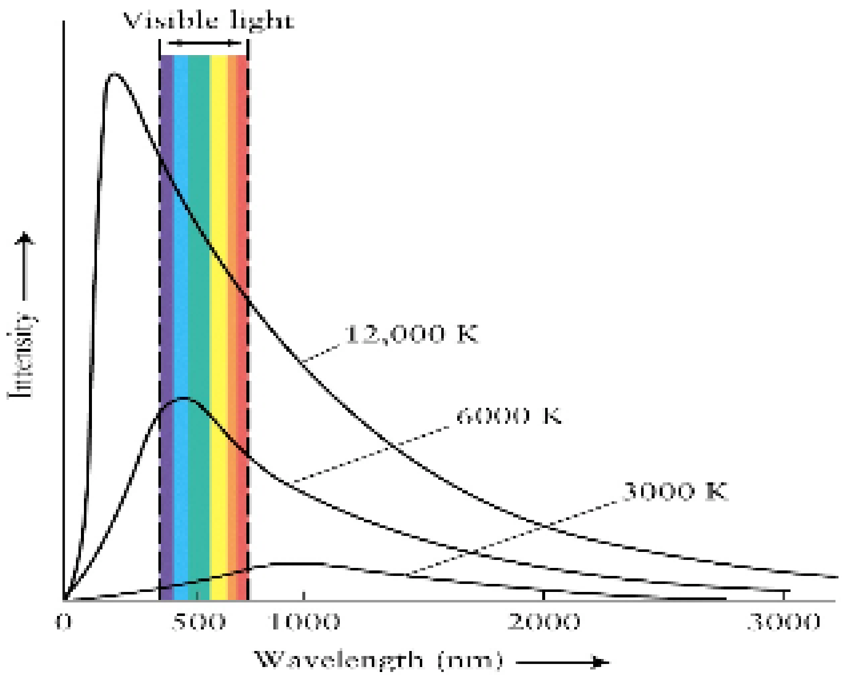
1. **Conduction** – (solids) the transfer of heat from molecule to molecule in a solid, with no net displacement of those molecules. (e.g. heat traveling up a metal spoon)
2. **Convection –** (liquids and gases) the transfer of heat through liquid and a gas due to buoyancy; colder fluid is more denser and therefore sinks, warmer fluid is less dense and therefore rises, setting up convection cells. (e.g. Hadley cell)
3. **Radiation** –(gases and vacuum) the transfer of heat through a vacuum. (e.g. short-wave radiation from the sun)

‡ A thermos bottles effectively stops all three forms of heat movement, which is why warm liquids retain their heat for so long. Double walls stop conduction, vacuum stops convection, and silver coating stops radiation.

Blackbody Radiation – The emission of radiation solely because of temperature. Our bodies are blackbody radiators. When ever you "wiggle" a charged particle, a photon comes out. Everything with heat releases photons of some energy and quantity.

Two characteristics of blackbody radiation are:

1. As you increase temperature, peak output moves to the left of the graph.
2. As you increase temperature, energies at all frequencies increases.



Thermal Equilibrium – when the heat loss of an object equals the heat absorbed by the object.

Spectral Lines

A hot glowing liquid, solid, or high density gas produces a **continuos** spectrum, essentially a black body curve.

If a continuous spectrum passes through a thin gas, the electrons in the gas will absorb those photons which allow perfect orbital jumps. Since the photons that meet this criteria will be absorbed (and thus missing). The spectra of the light coming through the gas will have dark lines (where the photons of a particular energy are missing). This spectra is called an **absorption** spectra.

The thin gas itself, now that it has many 'energized electrons', will glow with the light of all those electrons 'dropping back down to ground state'. The light will only be those spectral lines that correspond to the dark bands in the absorption spectra. A spectrum like this is called an **emission** spectrum.

Doppler Shift - The observed change in wavelength of a wave as a result of movement between the source and the receiver . Easily noticed with sound, but also happens with light.

Red Shift – Light from objects which are moving away from you are shifted towards longer wavelengths, and therefore the spectral lines will be shifted towards the red end of the spectrum.

Blue Shift – Light from objects which are moving towards you are shifted towards shorter wavelengths, and therefore the spectral lines will be shifted towards the blue end of the spectrum.

What we learn from studying spectral lines.

Radial velocity If the star is moving towards or away from us.

Rotation. When Doppler lines are thicker than usual, the object which is being viewed is rotating. The thickness of the spectral lines indicates how fast the object is rotating.

Binary Star? If the lines split into pairs, it indicates there are two starts rotating around each other.

Composition. Which lines are present tell us what the star in made of.

Interstellar gas is revealed if there are extra faint spectral lines on top of the star's spectrum. (visible because the I S gas has a different red or blue shift.)

Micro lensing – light bending.

Light bends are large things: light has a mass. So, as a planet gets close to a star, it will bend light. We can tell whether or not a star has a planet by looking for this for effect. The star will temporarily brighten when the planet passes in front of it.

Relativity

The speed of light is a constant 300,000 km/s. Further, the speed of light does not change when the source is moving [v=d/t], so therefore time slows down.

- Time is relative to the *viewer's motion.*

‡ *Time slows, mass increases, and length shortens in the direction of motion as an object approaches the speed of light.*

Relativity is a more accurate way of viewing the universe. It is more accurate then Newtonian mechanics, but the difference is usually negligible unless you are dealing with the following.

1) Speeds approaching the speed of light.
2) Gravitational forces around very massive objects.
3) Very precise timing.

KeyWords Chapter 5

Telescopes

- **Objective / Eyepiece**
- **History**
- **Detectors**
- **Refractors / Reflectors**
- **Orbital Observatories What and Why?**
- **Space Probes**

Telescopes

There are many different types of telescopes to detect and acquire data over the entire electromagnetic spectrum. Here on the ground, the only radiations that reach us from space in a useable form are visible light (the so called optical window, studied by optical telescopes) and radio waves (the radio window, studied by radio telescopes).

Optical telescopes have two main functions, to make objects brighter and to make objects bigger. Accordingly, the two most important pieces of an optical telescope are the **objective** and the **eyepiece**. The objective gathers light and makes far away objects appear brighter. The

eyepiece provides magnification and makes far away objects appear bigger.

There are two different types of optical telescopes, based on the type of objective being used. A **reflector** has a mirror for an objective, while a **refractor** has a lens for an objective.

History.

The first telescopes were single lens refractors, but they caused color distortion. Their only solution was to make the instruments of very long focal length, very awkward.

Then, after Newton demonstrated the reflecting telescope, people switched to reflectors using polished speculum, a pewter-like alloy. These were much more compact, but they had to be obsessively polished for maximum efficiency.

In the early 1800s, German opticians discovered new glass compositions that allowed for doublet objectives, which virtually eliminated the colour distortion. People returned to refractors, which steadily increased in aperture over the following 80 years. However, refractors can only reach 1 meter in diameter before they begin to buckle under their own weight.

By 1900, astronomers were back with reflectors, but now using polished 'front surface' mirrors. These increased in size over the next 50 years until the 200' Hale telescope was opened on Mount Polamar. This instrument dominated astronomical research for 30 years.

Finally, the advent of computers allowed cheaper thin plate mirrors to be controlled with electronics to produce excellent images. Current optical telescopes are all these computer controlled reflectors, whose objectives are composed of many smaller thin mirrors operating as one. Small mechanical actuators on the backs of the mirrors constantly adjust the glass to keep it 'optically perfect'.

Orbital Observatories:

We place instruments in orbit to avoid two things:

Some parts of the electromagnetic spectrum do not penetrate to the ground and thus must be observed from space. (Gamma Ray, X-ray, far infraRed and Long wave radio)

Even the optical and radio windows are somewhat distorted, so space based instruments often see 'clearer'.

Space Probes:

Although we can see much from here on the Earth, experience has shown that there is no substitute for actually getting close up to other worlds in our solar system by means of a space probe.